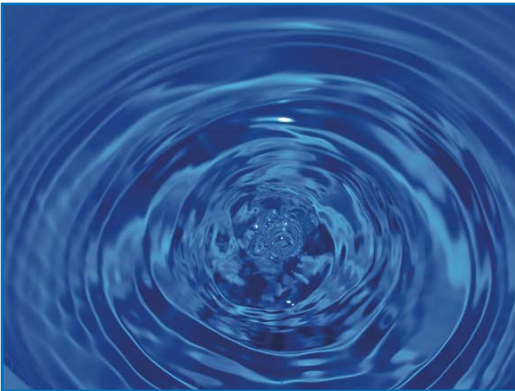


# Software Development for Drinking Water Security

*Regan Murray, PhD*  
*U.S. Environmental Protection Agency*



# Our Nation's Drinking Water: A Precious Resource



## Vulnerability to Terrorist Attacks

### Historical incidents:

- WWII – Japanese contaminated water in China with typhoid and anthrax
- Bosnian War – Yugoslavia contaminated 70% of wells in Kosovo with animal carcasses and toxic chemicals

### Current threats:

- Terrorists caught with blueprints of water system leading to US Embassy in Italy
- Al Qaeda has threatened US water supply



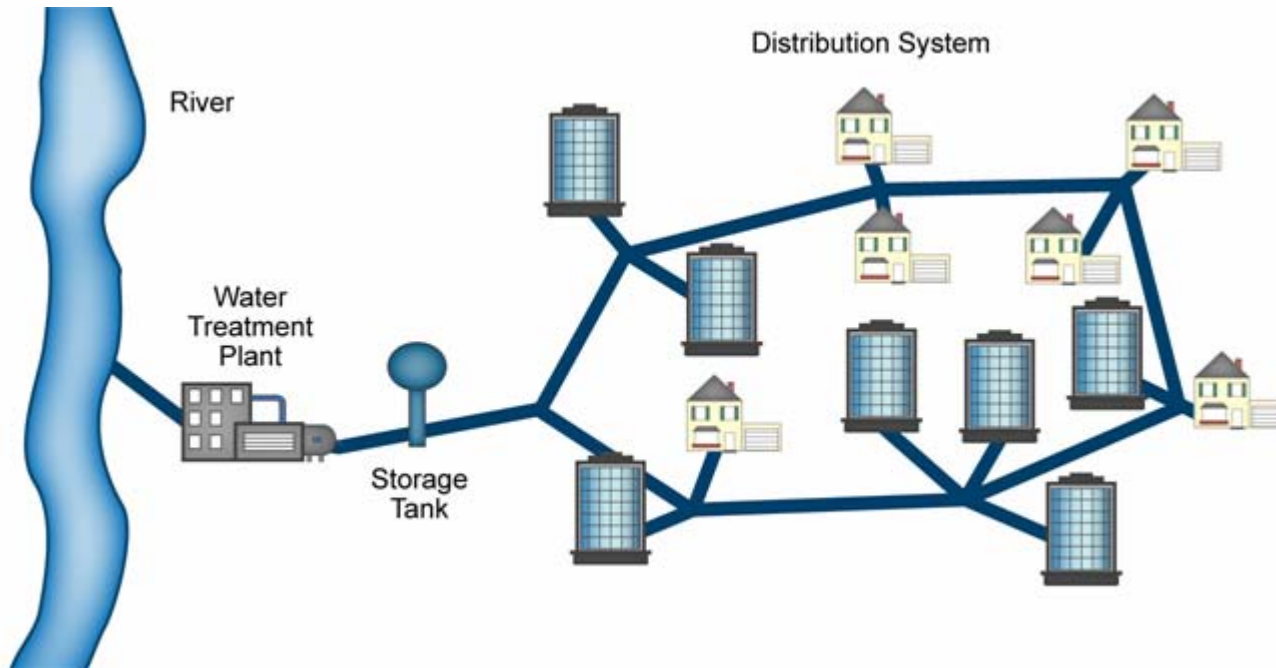
**DRINKING WATER SECURITY**  
*report suspicious activity*  
*at reservoirs*  
*at utilities*  
*at water mains*

**WE'RE ALL IN THIS TOGETHER**

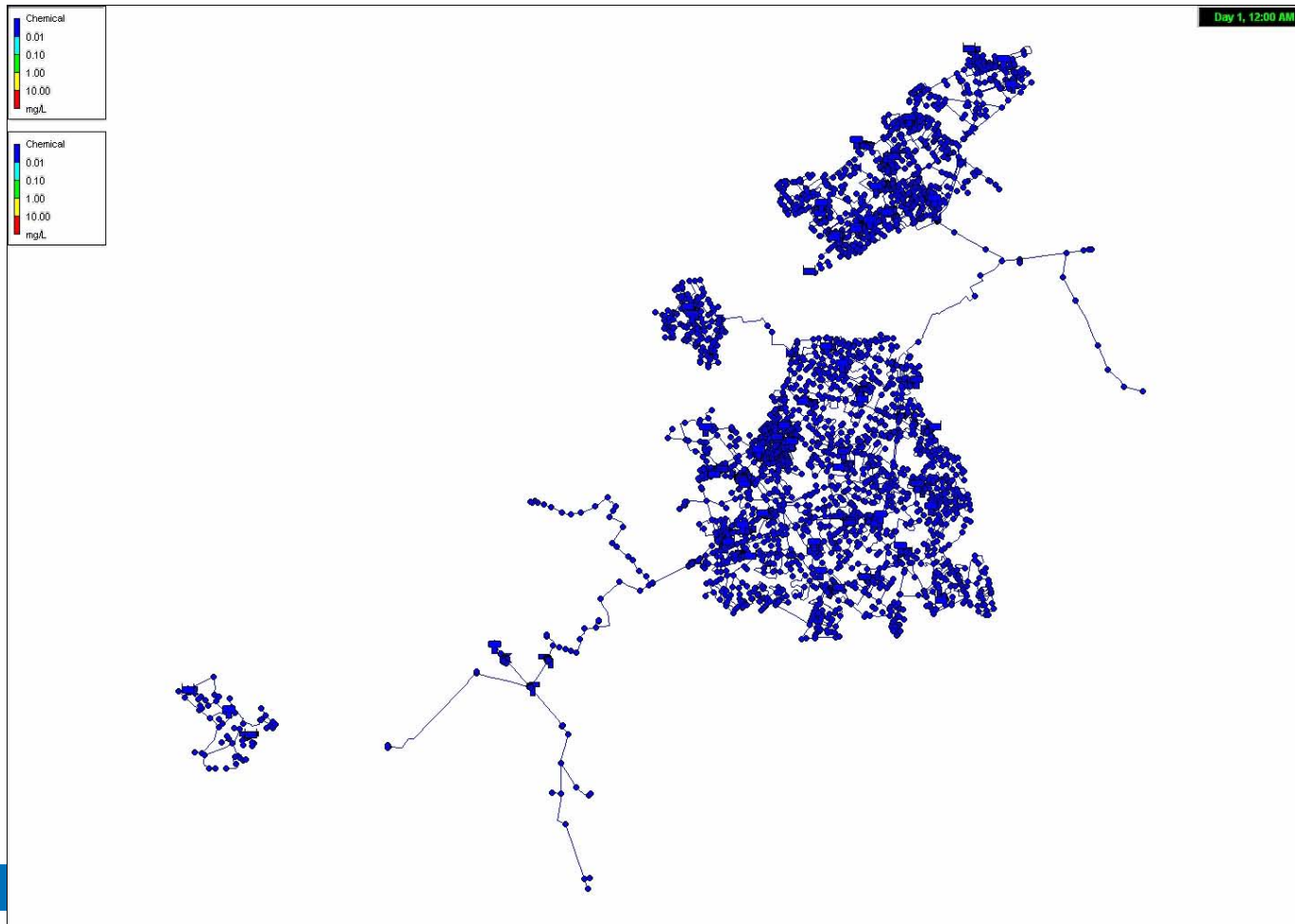
**FOR EMERGENCIES :** \_\_\_\_\_  
**FOR MORE INFORMATION :** \_\_\_\_\_

EPA United States Environmental Protection Agency [www.epa.gov/safewater/security](http://www.epa.gov/safewater/security) Office of Water (4606)  
EPA 810-F-03-001  
April 2003

## Main Components of Water Systems

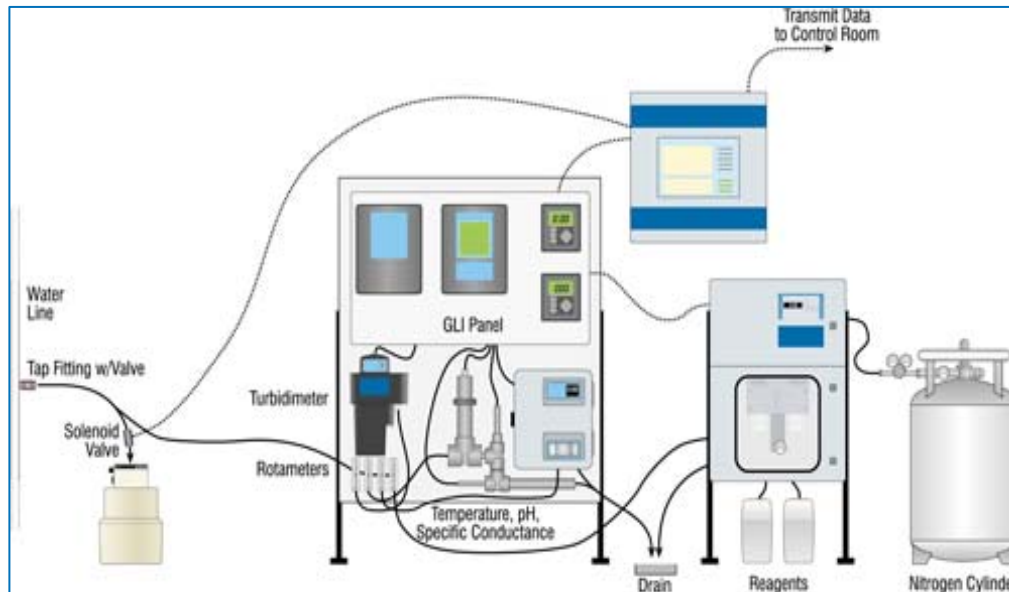


# Contamination of Water Distribution Systems



## Sensor Stations

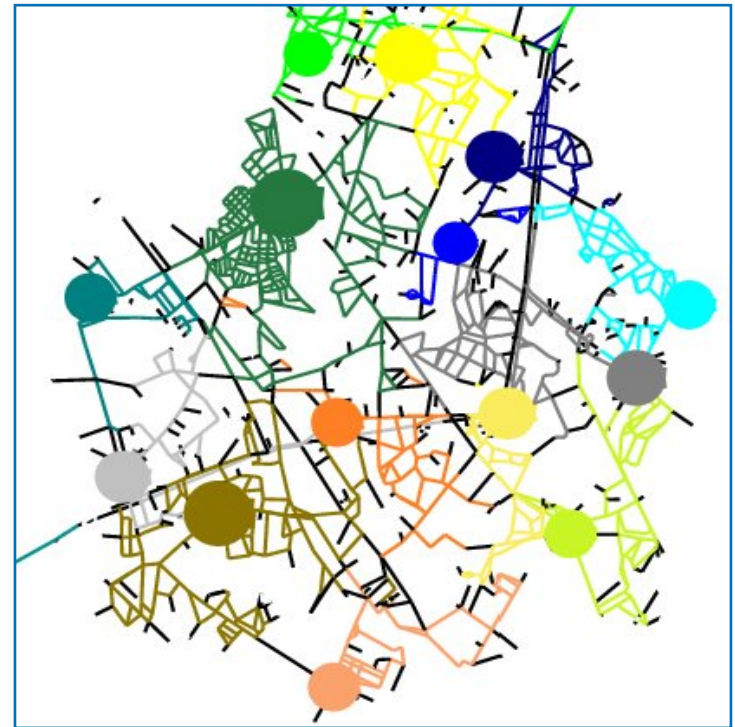
- Water utilities would like to install sensor stations to detect contaminants, introduced accidentally or intentionally
- They can cost \$20,000-\$50,000 each, so most utilities can only afford to install a small number of sensor stations



- Where should sensors be located?
  - Water tanks
  - Hospitals
  - Schools
  - Government offices
  - Other locations?

## Solving the Sensor Placement Problem

- Created a stakeholder group of water utilities and industry groups
- Formed an interdisciplinary team of scientists
- Formulated the problem
- Found multiple ways to solve the problem
- Tested the solutions
- Improved the methodology
- Pilot-tested methodology with utilities
- Developed user friendly software to allow water utilities to solve the problem themselves



## The Research and Stakeholder Teams

### *Research Team*

- EPA/NHSRC/WIPD
- EPA/NRMRL/WSWRD
- University of Cincinnati
- Argonne National Laboratory
- Sandia National Laboratories

### *Partners*

- American Water Works Association (AWWA)
- 9 Partner Utilities
- 22 Utilities

### *Objective*

- To develop quantitative methods to assess risk, design sensor networks to minimize that risk, and develop user friendly software to support water utilities.

## Project Planning for Quality

### • Research Team

- Quality Management Plan to guide entire team
- Quality Assurance Plans for Interagency Agreements with Argonne and Sandia National Laboratories
  - QA Plan integrated with Workplan identified QA practices for each work task
- Quality Assurance Plan for contract with University of Cincinnati

### • Stakeholder Group

- MOU between 9 partner utilities and EPA specified how both parties would manage sensitive information

# Mathematical Formulation of Sensor Placement Problem

The objectives for sensor placement can be formalized mathematically as integer programs

Objective:

$$\sum_{a \in A} \sum_{i \in L} \alpha_a w_{ai} x_{ai}$$

- $\alpha$  – attack likelihood
- $w$  – attack impact
- $x$  – attack witness variable
- $s$  – sensor placement variable

$$\begin{aligned} &\text{minimize} && \sum_{a \in A} \sum_{i \in L} \alpha_a w_{ai} x_{ai} \\ &s.t. && \\ &&& \sum_{i \in L} x_{ai} = 1 && \forall a \in A \\ &&& x_{ai} \leq s_i && \forall a \in A, i \in L \\ &&& \sum_{i \in L} s_i \leq S_{\max} \\ &&& s_i \in \{0,1\} \end{aligned}$$

- “Impact” can be measured in several ways: number of people exposed, time of detection, extent of contamination, etc.

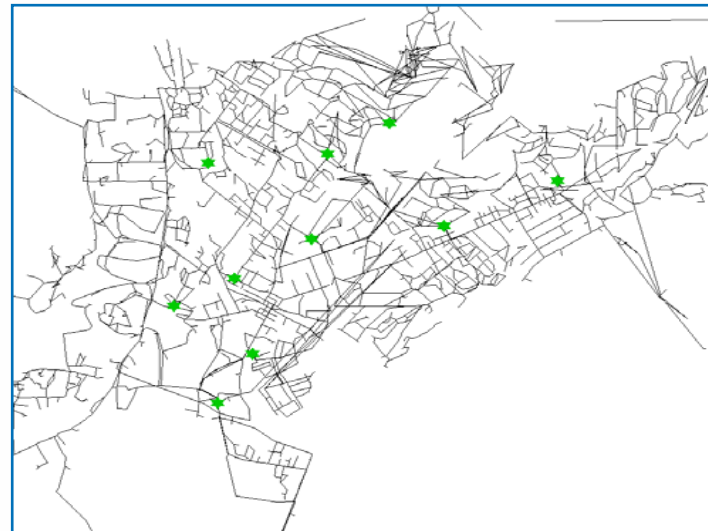
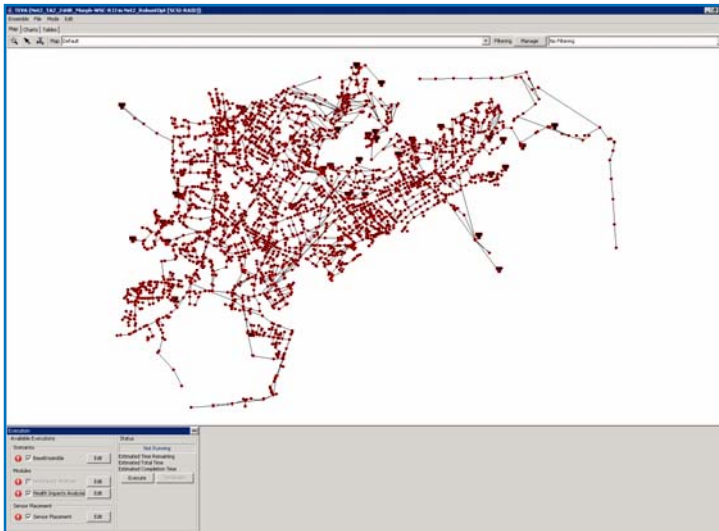
## Formulating model and developing solution methods

- Computational methods for solving the problem were identified and a simple software package was created to test these methods
- Best practices for software development
  - **Developers listserve** to send automated emails when code is changed
  - **Software Version Repository** to track all changes to code
  - **Bug reporting** and automated emails to report bugs and assign someone to fix the bugs
  - **Automated nightly testing** to ensure code continues to work
  - **Quarterly software releases** to project team with full testing suite

## Testing the initial solution methods

- TEVA-SPOT “Utility Requirements” developed to communicate to water utilities about the input data needed to run software
- Nine utility partners signed MOU’s to share data with EPA
- On secure computer systems, EPA staff tested software utility data
  - Identified limitations of software
  - Found bugs in the code
  - Highlighted improvements to make software easier to use

# TEVA-SPOT (Threat Ensemble Vulnerability Assessment – Sensor Placement Optimization Tool) Software



## Getting Software to Users



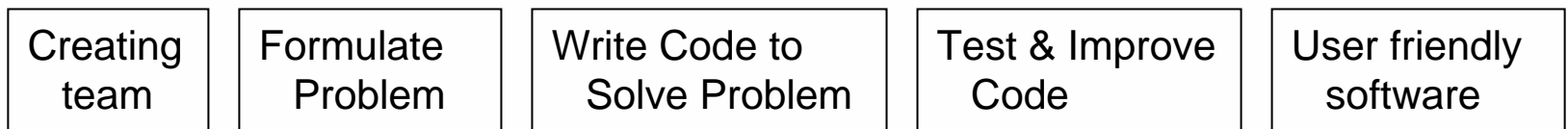
- **Availability**

- Software tool available to water utilities that solves the sensor placement problem even for very large networks
- Open source software available for researchers and software vendors to modify and improve
- Meeting with vendors to develop partnership

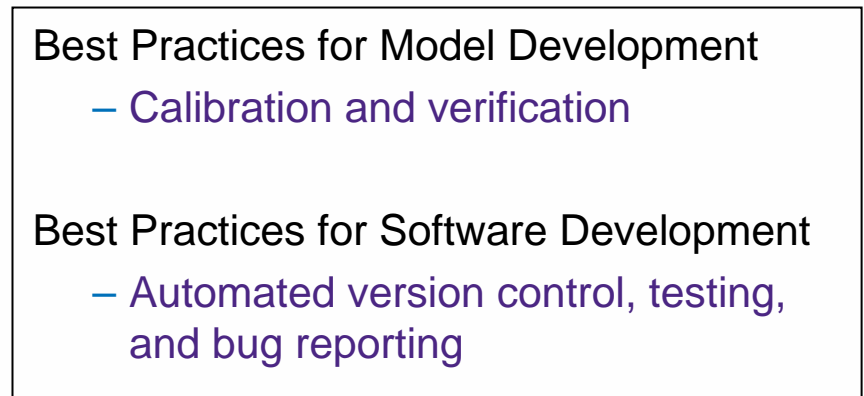
- **Training**

- Trained more than 75 utilities and consultants at a workshop, April 2008
- Trained new Water Security Initiative utilities in a webinar, October 2008
- Additional training planned in 2009

## Ensuring Quality for TEVA-SPOT applications



### All steps in project guided by quality practices:



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